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Median Guard Cable Performance in Relation with Median Slope on Interstate 70

Prepared by
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Transportation

Final Report

RI08-039

**Median Guard Cable Performance in
Relation with Median Slope
Study on I-70**

Prepared for
Missouri Department of Transportation
Organizational Results

by

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Missouri Department of Transportation

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The opinions, findings, and conclusions expressed in this publication are those of the principal investigators and the Missouri Department of Transportation. They are not necessarily those of the U.S. Department of Transportation, Federal Highway Administration. This report does not constitute a standard or regulation.

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16. Abstract The current study was conducted along the entire Interstate 70 to investigate how median slopes influence guard cable effectiveness. It was found out that the success rates for guard cables installed on both steeper and flatter slopes are high. Median slope does not solely affect guard cable effectiveness. Factors such as vehicle type, roadway horizontal and vertical alignment, and guard cable horizontal distance, do not solely contribute to the effectiveness of guard cable either. The inclusion of crash related data such as vehicle speed and collision angle could make it possible to get a more complete capture of guard cable performance. However, that data is not available at this time.			
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EXECUTIVE SUMMARY

In recent years, Missouri has seen large-scale installation of median guard cable along major highways as a relatively inexpensive and effective way of preventing crossover crashes. Although it is believed that 6H:1V is the maximum median slope for median guard cable to be effective, in practice, slopes that are steeper than 6H:1V are often encountered. Considering these exceptions, MoDOT intended to find out the performance of median guard cables in relation to median slopes.

A preliminary study conducted in 2006 on I-44 showed that there is no statistically significant difference of success rate between guard cables installed on medians with flatter ($\geq 6\text{H:1V}$) and steeper slopes ($< 6\text{H:1V}$). That is to say, steepness of the slope alone does not cause the median guard cable to fail any more or less. Considering the limited sample size (225) for the study along I-44, FHWA and other research facilities recommended a larger data set be collected to lend the study more credibility.

The main purpose of the current study is to find out how median slopes influence guard cable effectiveness based on analysis of the larger data set. The entire Interstate 70 was chosen to conduct the current study. A total of 521 survey forms representing the 521 identified crash sites (study goals) were distributed to the involved districts to collect median and crash data.

Data analysis showed that the success rates for guard cables installed on both steeper and flatter slopes are high. Median slope does not solely affect guard cable effectiveness. Factors such as vehicle type, roadway horizontal and vertical alignment, and guard cable horizontal distance, do not solely contribute to the effectiveness of guard cable either. The inclusion of crash related data such as vehicle speed and collision angle could make it possible to get a more complete capture of guard cable performance. However, that data is not available at this time.

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1 Introduction

The low-tension guard cable system consists of steel cable mounted on weak posts. When a vehicle impacts the low-tension system under normal conditions, the cable deflects as much as 12 feet from its original location. It is believed to be a relatively inexpensive and effective way of preventing crossover crashes on highways. In recent years, Missouri has seen large-scale installation of median guard cable along major highways including I-70, I-270, I-44, I-55, and I-435.

Computer modeling and full-scale crash testing found that 6H:1V is the maximum median slope for median guard cable to be effective. The AASHTO roadside design guide says that “the cable barrier remains effective when mounted on a moderate slope (up to 6H:1V)”. However, in practice, slopes that are steeper than 6H:1V are often encountered. For example, MoDOT installed 80 miles of cable in the median of I-70 on slopes that are as steep as 5H:1V. Median guard cables are also installed on steeper slopes on I-44.

Considering these exceptions, MoDOT intended to find out the performance of median guard cables in relation to median slopes. A preliminary study was conducted in 2006 on I-44. In this preliminary study, a total of 225 crashes from 1999 to 2005 involving with guard cables were investigated. A field survey was conducted to collect crash sites information, which include median slope, median type and characteristics (stepped median, ditch section, erosion control, etc.), non-standard guard cable appearance (lateral placement, height of cable, post spacing, and post installation type). Data analysis showed that there is no statistically significant difference of success rate between guard cables installed on medians with flatter ($\geq 6\text{H:1V}$) and steeper slopes ($< 6\text{H:1V}$). That is to say, steepness of the slope alone does not cause the median guard cable to fail any more or less.

The preliminary results are quite positive and have attracted national attention. Considering the limited sample size (225) for the study along I-44, FHWA and other research facilities recommended a larger data set be collected to lend the study more credibility. The main purpose of the current study is to find out how median slopes influence guard cable effectiveness based on analysis of the larger data set.

2 Study Procedure

To fulfill the goal of collecting more data to evaluate guard cable effectiveness in relation to median slopes, the entire Interstate 70 was chosen. The following two reasons explained why I-70 was chosen for this in-depth study:

- The more than 500 crashes in I-70 accident set makes a legitimate sample size
- Rural and urban settings along I-70 exhibit varied terrain

Once the corridor was chosen and crash sites were identified for the involved districts (D2, D3, D4, D5, and D6), survey forms were distributed to those districts. The forms were designed for survey crew to collect median data. Each survey form lists the same blank items (such as Ditch Type, Ditch Width, Offset, Median Slope, etc.) but had filled crash site information (such as Form Number, Crash Image Number, Continuous Log Mile, Cable Success or Failure, etc.). A copy of the survey form and the instructions to fill it out can be found in Appendix A and B.

One item in the survey form that needs to be noticed for data collection is the median slope that will be used in the study. After discussing the typical I-70 median cross sections with Traffic, MoDOT staff agreed to use the critical slope (closest to the shoulder) to correlate the median guard cable effectiveness with the slope. Only if the secondary slope has a longer run than the critical slope, should the secondary slope be used. So in practice, slope information for both runs were collected, but only one of them was used in data analysis regarding the effect of median slope on guard cable performance.

Table 2.1 Crash Data Distribution by Year

Year	2000	2001	2002	2003	2004	2005	Total
Count of Crashes	4	2	35	40	145	295	521

A total of 521 survey forms representing the 521 identified crash sites (Table 2.1 shows the distribution of these crashes by year) were distributed to the involved districts. All distributed forms were collected back. After the completed forms were reviewed, 18 of them were excluded from the final data analysis due to one of the following two reasons:

- Not enough information was collected
- Very deviated median geometric design and guard cable installation

This filter process resulted in a total of 503 crash sites for this study. Table 2.2 lists distribution of crashes by district and county. This study used the same definition for “success” and “failure” as used in the preliminary study on I-44. When a vehicle crashes into a guard cable, the performance of the guard cable is defined as “success” if that vehicle does not make it to the opposing travel lanes. Otherwise, it means “failure”.

Table 2.2 Crash Data Distribution by County

District	County	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
2	Saline	23	1	4.3%	22	95.7%
3	Montgomery	108	4	3.7%	104	96.3%
	Warren	107	2	1.9%	105	98.1%
4	Jackson	53	1	1.9%	52	98.1%
	Lafayette	69	3	4.3%	66	95.7%
5	Boone	20	1	5.0%	19	95.0%
	Callaway	75	8	10.7%	67	89.3%
	Cooper	7	0	0.0%	7	100.0%
6	St. Charles	41	2	4.9%	39	95.1%
Total		503	22	4.4%	481	95.6%

3 Data Analysis and Results

Several statistical analyses were run for different topics based on which variable was the focus. For example, to find out whether median slope is a critical factor in deciding the success rate for guard cable, the success rates for both steeper ($<6H:1V$) and flatter ($\geq 6H:1V$) slopes were

calculated separately and then compared on a certain statistical significance level (see Table 3.2). To make it better reflect how median slopes affect guard cable effectiveness, slopes were even further categorized into smaller groups such as <4H:1V, <5H:1V, <6H:1V, etc. (see Table 3.3). In addition to median slope, other factors such as vehicle type, roadway horizontal alignment, and guard cable offset distance, etc. were also taken into consideration when comparing the success rate. Results from these statistical analyses are presented in this section.

3.1 Guard Cable Performance in Relation to Median Slope

Table 3.1 is a summary of median slope information for all crash sites.

Table 3.1 Summary of Median Slope

Item	Maximum	Minimum	Median	Average
Median Slope (H:V)	100:1	3.1:1	6.45:1	7.73:1

Table 3.2 Median Slope vs. Guard Cable Performance

Median Slope	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
≥ 6 (flatter)	296	18	6.1%	278	93.9%
< 6 (steeper)	207	4	1.9%	203	98.1%
Total	503	22	4.4%	481	95.6%

Among the 503 guard cable crashes, 296 of them happened on slopes that are equal to or flatter than 6H:1V ($\geq 6\text{H:1V}$) with 18 failures and a success rate of 93.9%. The success rate for cables on slopes steeper than 6H:1V ($< 6\text{H:1V}$) is 98.1% with 4 failures out of 207 crashes. Chi-square test (χ^2 test), which is used to compare groups to determine whether the observed differences are statistically significant, was used to find out if there is real difference in median guard cable success rates between flatter and steeper slopes. Results showed that the difference is statistically significant (with a confidence level of 95%). Contrary to the belief that steeper slopes are associated with higher failure rates, this study showed guard cables on steeper slopes had a lower failure rate. Due to the fact that other factors such as crash speed, collision angle, vehicle type, and cable installation condition are not considered, caution should be used in making a conclusion regarding guard cable performance on flatter vs. steeper slopes. In the next section, vehicle type will be included in the data analysis.

Table 3.3 Median Slope vs. Guard Cable Performance

Median Slope (H:V)	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
$S < 4$ (steeper)	26	0	0.0%	26	100.0%
$4 \leq S < 5$	71	1	1.4%	70	98.6%
$5 \leq S < 6$	110	3	2.7%	107	97.3%
$6 \leq S < 10$	214	11	5.1%	203	94.9%
$10 \leq S < 20$	70	6	8.6%	64	91.4%
$S \geq 20$ (flatter)	12	1	8.3%	11	91.7%
Total	503	22	4.4%	481	95.6%

3.2 Guard Cable Performance in Relation to Vehicle Type

It is believed that speed played a vital role in deciding the success of median guard cable. However, crashing speed information couldn't be identified for each crash case, so it was not included as a variable in the statistical analysis.

To find out if a certain vehicle type is more related to guard cable crash failure, the performance of median guard cable was analyzed in relation to the vehicle type. This study used the same way that vehicles were classified in the I-44 study. All vehicles in this study were identified as one of the following three types based on their curb weights.

- Car - 3300 lbs
- SUV/Truck - 4300 lbs
- Semi-Truck - 80,000 lbs

Table 3.4 Median Slope vs. Guard Cable Performance by Vehicle Type

Car					
Median Slope	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
≥6 (flatter)	185	9	4.9%	176	95.1%
<6 (steeper)	117	4	3.4%	113	96.6%
Total	302	13	4.3%	289	95.7%
SUV/Truck					
Median Slope	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
≥6 (flatter)	88	6	6.8%	82	93.2%
<6 (steeper)	77	0	0.0%	77	100.0%
Total	165	6	3.6%	159	96.4%
Semi-Truck					
Median Slope	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
≥6 (flatter)	21	2	9.5%	19	90.5%
<6 (steeper)	13	0	0.0%	13	100.0%
Total	34	2	5.9%	32	94.1%
Other					
Median Slope	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
≥6 (flatter)	2	1	N/A	1	N/A
<6 (steeper)	0	0	N/A	0	N/A
Total	2	1	N/A	1	N/A

As can be seen from Table 3.4 among the 503 crashes, 302 involved cars (60%), 165 involved SUV/Truck (32.8%), 34 involved semi-trucks (6.8%), and 2 involved other unidentified vehicles (0.4%). For each type of vehicle, failure rates under both flatter and steeper slope conditions are

calculated (see Table 3.4). Chi-square test for each vehicle type showed that, for Car and Semi-Trucks there is no statistically significant difference in guard cable success/failure rate between two median groups (flatter vs. steeper). For SUV/Truck, there is a statistically significant difference between the two median groups with a higher failure rate on flatter slopes. Without other factors such as crash speed and angle taken into consideration, however, the conclusion that guard cables on steeper slopes have a better performance for SUV/Truck still cannot be reached.

On the other hand, the fact that guard cable failure rate is higher on flatter slopes for all vehicle types indicates that slope is not the single factor that contributes to guard cable performance.

3.3 Guard Cable Performance in Relation to Horizontal Distance

Horizontal distance represents the distance from edge of shoulder to median guard cable. Survey forms used the terms “OffsetEB” and “OffsetWB” to collect this information. Table 3.5 lists the summary of horizontal distance for all crash sites.

Table 3.5 Summary of Horizontal Distance

Item	Maximum	Minimum	Median	Average
Horizontal Distance (ft)	31	2.17	16	15.66

Two groups were compared based on length of horizontal distance, one with shorter distance (≤ 15 ft) and the other with longer distance (> 15 ft).

Table 3.6 Horizontal Distance vs. Guard Cable Performance

Horizontal Distance	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
≤ 15 ft	173	8	4.6%	165	95.4%
> 15 ft	330	14	4.2%	316	95.8%
Total	503	22	4.4%	481	95.6%

Statistical analysis does not show that horizontal distance makes a difference in the success or failure of median guard cable.

3.4 Guard Cable Performance in Relation to Roadway Horizontal Alignment

Roadway horizontal alignment was identified as curve or tangent (straight).

Table 3.7 Horizontal Alignment vs. Guard Cable Performance

Horizontal Alignment	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
H-Curve	113	6	5.3%	107	94.7%
H-Tangent	390	16	4.1%	374	95.9%
Total	503	22	4.4%	481	95.6%

Among the 503 crashes, 390 of them (78%) happened on roadways with tangent horizontal alignment and the rest (22%) on curve horizontal alignment. Although success rate for tangent

horizontal alignment (95.9%) is slightly higher than curve horizontal alignment (94.7%), chi-square test does not show that this difference is statistically significant.

3.5 Guard Cable Performance in Relation to Roadway Vertical Alignment

Similar analysis with vertical alignment showed that vertical alignment is also not a contributing factor in deciding median guard cable success or failure.

Table 3.8 Vertical Alignment vs. Guard Cable Performance

Vertical Alignment	Count of Crashes	Count of Failure	Failure Rate	Count of Success	Success Rate
V-At Grade	221	13	5.9%	208	94.1%
V-Curve	139	6	4.3%	133	95.7%
V-Flat	141	3	2.1%	138	97.9%
V-Other	2	0	N/A	2	N/A
Total	503	22	4.4%	481	95.6%

4 Accident Severity and Injury Level

Table 4.1 lists the distribution of accident severity (fatal, injury, or PDO) under guard cable success and failure conditions.

Table 4.1 Accident Severity Distribution by Guard Cable Success/Failure

Accident Severity	Count of Failure	Count of Success
Fatal	1	3
Injury	11	49
PDO	10	429
Total	22	481

Accident Severity of Failure Cases

Accident severity of Success Cases

As can be seen from Table 4.1, compared with success cases, crashes where guard cable failed were more likely to be fatal or injury. The fatal rates for failure and success cases are 4.5% and

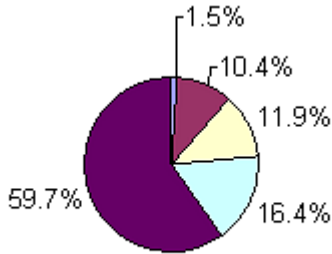
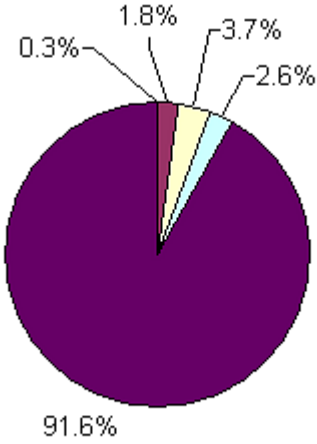
0.6% respectively; the injury rates 50.0% and 10.2%. A majority (89.2%) of the success cases was Property Damage Only (PDO) while only less than half (45.5%) of failure ones fell into the same category.

A total of 943 people were involved in the 503 crashes. Among these people, 67 were involved in failure cases, and 876 in success cases. The original accident reports were used to collect individual injury level information. Table 4.2 lists the distribution of these people's injury levels by failure/success. The same method specified in the Missouri Uniform Accident Report Preparation Manual was used to classify injury level here:

- Level 1 – Fatal
- Level 2 – Disabling
- Level 3 – Evident – Not Disabling
- Level 4 – Probable – Not Apparent
- Level 5 – None Apparent

Table 4.2 People Injury Level Distribution by Guard Cable Success/Failure

Injury Level	Count of People in Failure	Count of People in Success
Level 1 (fatal)	1	3
Level 2 (disabling)	7	16
Level 3 (evident)	8	32
Level 4 (probable)	11	23
Level 5 (none apparent)	40	802
Total	67	876

 <p>Injury Level of People in Failure Cases</p>	 <p>Injury Level of People in Success Cases</p>
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As Table 4.2 showed, compared with success cases, failure cases involved higher rates of fatal, disabling, evident, and probable injuries. The findings in this section provided solid proof that median guard cable is an effective way to improve safety and save lives.

5 Conclusion

Overall, median guard cable is an effective safety measure with an average of 95.6% success rate in preventing vehicles encroaching into opposing lanes along I-70. The success rates for guard cables installed on both steeper and flatter slopes are pretty high, with 98.1 % for steeper slopes and 93.9% for flatter ones. The fact that guard cable success rate for steeper slopes ($<6H:1V$) is not any lower than the rate for flatter slopes ($\geq 6H:1V$) showed that median slope does not solely affect guard cable effectiveness. Other factors (e.g., crash speed, collision angle, etc.) also contribute to the success or failure of median guard cable in keeping vehicles from encroaching into the opposite lane.

Similar statistical analyses show that other factors such as vehicle type, roadway horizontal and vertical alignment, and guard cable horizontal distance, do not solely contribute to the effectiveness of guard cable too.

The above conclusion made it clear that geometrical characteristics are not the only contributing factors deciding median guard cable performance. Crash related factors such as vehicle speed and collision angle are needed to capture a more accurate picture of guard cable performance. However, due to the fact that it might be impossible to collect this information, these factors were not included in this study. If crash related data as mentioned above could be collected, more advanced statistical analysis tools could be used to investigate overall median guard cable performance.

Comparison between failure and success cases showed an obvious trend in accident severity and injury level. Guard cable failures are always involved with higher rates of severe crashes and individual injuries.

MEDIAN GUARD CABLE SURVEY DATA

Form Number General Location

Image Accident Date:

County Accident Seveity

Route

Cont. log mile

Success

Vehicle

Horizontal Alignment

- ☐ Tangent
- ☐ Curve
- ☐ Other

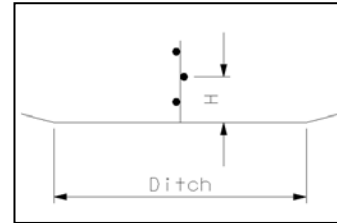
Vertical Alignment

- ☐ At Grade
- ☐ Curve
- ☐ Flat
- ☐ Other

Cross-Section

- ☐ Normal Crown
- ☐ SuperElevation
- ☐ Other

Ditch



Ditch Width

Mid Cable Height

Ditch Type

- ☐ Flat
- ☐ V-Shape
- ☐ Other

Middle Cable Faces:

- ☐ EB
- ☐ WB

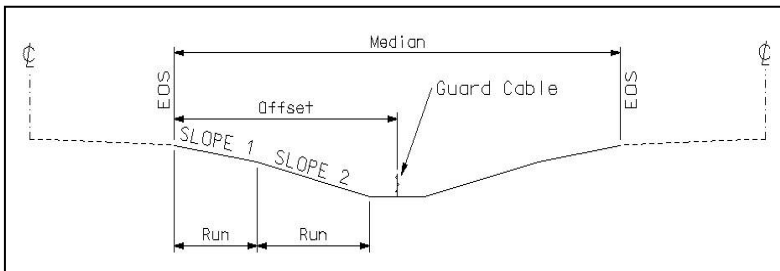
Cables Down

- ☐ Yes
- ☐ No

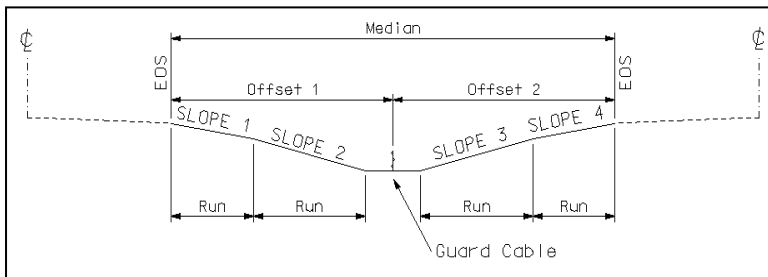
Rock Blanket

- ☐ Yes
- ☐ No

Single Survey



Double Survey



Survey Type

- ☒ Single
- ☐ Double

Survey Date:

Survey By:

OffsetEB

OffsetWB

Run 1

Run 2

Run 3

Run 4

Slope 1

Slope 2

Slope 3

Slope 4

Additional Guard Cable Notes and Sketch

Appendix B Survey Form Instructions

Data Field	Direction*
Horizontal Alignment:	Enter the current horizontal alignment. The alignment is typically Tangent (Straight) or Curved.
Vertical Alignment:	Enter the current vertical alignment. The alignment is typically At Grade (Uphill or Downhill), Curve (top or bottom of a vertical curve), or Flat.
Cross-Section:	Enter the Roadway cross-section type, typically Normal Crown (^) or Superelevated (/ or \).
Ditch Type:	Enter the median ditch type.
Middle Cable Faces:	By looking at the nearest 3-cable system post, one can see that the middle cable and the two-outer cables face opposite travelways. The middle cable should face either IS 70EB or IS 70WB.
Cables Down:	Select "yes" if at the time of the survey the cables are down (excessive sag.)
Rock Blanket:	Select "yes" if at there is rock lining where the 3-cable system is located.
Ditch Width:	Enter the width of the Median ditch.
Mid Cable Height:	Please measure the vertical distance between the ground to the middle cable.
Survey Date:	Enter the date in which the survey was completed.
Survey By:	Enter the name of the surveyor (s).
OffsetEB:	If the Route field reads "IS_70EB", provide the distance from the guard cable to the EOS of IS 70EB. If the survey type has been marked as "Double", please provide the distance from the guard cable to the EOS of IS 70WB too.
OffsetWB:	If the Route field reads "IS_70WB", provide the distance from the guard cable to the EOS of IS 70WB. If the survey type has been marked as "Double", please provide the distance from the guard cable to the EOS of IS 70EB too.
Run 1	Enter the distance between the EOS (IS 70EB or IS 70WB) to the median guard cable.
Slope 1	Enter the median slope (Horizontal:Vertical).
Run 2	If more than one median slope, enter the second run.
Slope 2	If more than one median slope, enter the second median slope (H:V).
Run 3	If the survey type has been marked as "Double," enter the opposite slope run.
Slope 3	If the survey type has been marked as "Double," enter the opposite median slope (H:V).
Run 4	If the survey type has been marked as "Double," enter a second opposite slope run.
Slope 4	If the survey type has been marked as "Double," enter a second opposite median slope (H:V).

* There are two types of surveys: "Single" and "Double." In a Single survey, only the part of the median between the cable system and the corresponding route are necessary. In a Double survey, the entire median should be described. See the "Single Survey" and "Double Survey" pictures included in the form.



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